

OPTICAL PREAMPLIFIER WITH  
RECEIVED SIGNAL STRENGTH INDICATING FUNCTION

## Cross-Reference to Related Applications

This application claims the benefit of U.S. Provisional Application Number 60/427,439, filed 19 November 2002.

#### Field of the Invention

This invention relates to optical preamplifiers and, more particularly, to optical preamplifiers including received signal strength indications or indicators.

## Background of the Invention

Optoelectronics is a rapidly expanding technology that is an important component in modern communications systems wherein it is desired to transmit vast amounts of data over long distances in a short period of time. With the increasing commercial applications for optoelectronic systems, there is a need to develop cost effective and reliable optoelectronic devices for use in optical communications systems.

1       Typical fiber optic systems include an optical  
2       preamplifier which detects incident light from an optical fiber  
3       and converts the light into an amplified electrical signal. In  
4       one application, the incident light is incident onto a PIN  
5       photodiode which is electrically connected to the preamplifier.  
6       It is desirable, however, to be able to measure the intensity  
7       of the light incident onto the PIN photodiode. This can be  
8       accomplished by using a received signal strength indicator  
9       (hereinafter referred to as "RSSI"). The RSSI typically  
10      includes a resistor electrically connected in series with the  
11      PIN photodiode wherein the current through the PIN photodiode  
12      can be measured at an outside lead to measure the intensity of  
13      the incident light. This solution can be accomplished by  
14      increasing the number of leads required for the system. It is  
15      well known by those skilled in the art, however, that  
16      increasing the number of leads increases the system cost and  
17      complexity. Thus, it is desirable to add the RSSI function to  
18      the optical preamplifier without increasing the number of  
19      leads.

20

21       It would be highly advantageous, therefore, to remedy the  
22      foregoing and other deficiencies inherent in the prior art.

1        Accordingly, it is an object the present invention to  
2 provide a new and improved optical preamplifier with a received  
3 signal strength indicator function.

4

5        Another object of the present invention is to provide a  
6 new and improved optical preamplifier having a received signal  
7 strength indicator function with reduced cost and complexity.

8

9        Another object of the present invention is to provide a  
10 new and improved optical preamplifier including a received  
11 signal strength indicator function, with fewer leads.

## Summary of the Invention

Briefly, to achieve the desired objects of the instant invention in accordance with a preferred embodiment thereof, an optical preamplifier with received signal strength indicating function is disclosed. The optical preamplifier includes an amplifier stage having a signal input, two signal output terminals, a power input terminal, and a return terminal. A photodiode has one terminal coupled to the signal input of the amplifier stage and a second terminal coupled through a resistance to one of the two signal output terminals so as to provide the received signal strength indicating function between the two signal output terminals.

In one embodiment, an optical preamplifier with received signal strength indicating function is disclosed that does not increase the number of terminals. The preamplifier includes an amplifier stage having cascaded amplifiers and a current mode output stage with Darlington pair transistors. The amplifier stage has a signal input to the cascaded amplifiers, two signal output terminals from the Darlington pair transistors, a power input terminal, and a return terminal. A PIN photodiode has one terminal coupled to the signal input of the amplifier stage and a second terminal coupled through a resistance to one of the two signal output terminals so as to provide the received

1 signal strength indicating function between the two signal  
2 output terminals.

3

4 The desired objects of the instant invention are further  
5 realized in method of providing an optical preamplifier with a  
6 received signal strength indicating function without increasing  
7 the number of leads. The method includes the steps of:  
8 providing an amplifier stage having a signal input, two signal  
9 output terminals, a power input terminal, and a return  
10 terminal; coupling one terminal of a photodiode to the signal  
11 input of the amplifier stage; and coupling a second terminal of  
12 the photodiode through a resistance to one of the two signal  
13 output terminals so as to provide the received signal strength  
14 indicating function between the two signal output terminals.

#### Brief Description of the Drawings

3 The foregoing and further and more specific objects and  
4 advantages of the instant invention will become readily  
5 apparent to those skilled in the art from the following  
6 detailed description of a preferred embodiment thereof taken in  
7 conjunction with the drawings, in which:

9 FIG. 1 is a circuit schematic of a preamplifier with four  
10 leads, wherein the preamplifier is electrically connected to a  
11 PIN photodiode;

12  
13 FIG. 2 is a circuit schematic of a preamplifier with five  
14 leads which includes a received signal strength indicator,  
15 wherein the preamplifier is electrically connected to a PIN  
16 photodiode;

18 FIG. 3 is a more detailed circuit schematic of the  
19 preamplifier of FIG. 1, with four leads;

21 FIG. 4 is a circuit schematic of a preamplifier with four  
22 leads which includes a received signal strength indicator,  
23 wherein the preamplifier is electrically connected to the  
24 photodiode, in accordance with the present invention; and

1 FIG. 5 is a more detailed circuit schematic of a  
2 preamplifier, with four leads including the received signal  
3 strength indicator, in accordance with the present invention.

#### DETAILED DESCRIPTION OF THE DRAWINGS

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3           Turning now to FIG. 1, a simplified circuit schematic of  
4   an optical preamplifier 5 is illustrated. Here it will be  
5   understood that FIGS. 1, 2, and 3 are included to aid in  
6   providing an example of individual components and problems  
7   encountered in the field of the present invention and solved in  
8   the present invention. Preamplifier 5 includes an amplifier 12  
9   with an input connection 30, a positive voltage output  
10   connection 33, a negative voltage output connection 32, a  
11   current return connection 31, and a power connection 34.  
12   Current return connection 31 is electrically connected to a  
13   current return lead 13, positive voltage output connection 33  
14   is electrically connected to a lead  $V_{out}^+$ , negative voltage  
15   output connection 32 is electrically connected to a lead  $V_{out}^-$ ,  
16   and power connection 34 is electrically connected to a lead  $V_{cc}$   
17   at a node 15.  $V_{out}^+$  and  $V_{out}^-$  are typically RF coupled to a  
18   current limiting amplifier (not shown). It will be understood  
19   that optical preamplifier 5 is typically formed as an  
20   integrated circuit on a chip and that current return lead 13,  
21   lead  $V_{out}^+$ , and lead  $V_{out}^-$  provide a means for electrical  
22   communication outside of the chip.

1       Input connection 30 is electrically connected to a  
2 terminal of a PIN photodiode 10. PIN photodiode 10 is used to  
3 detect light 11 from an optical fiber (not shown) or the like  
4 wherein light 11 creates a photocurrent,  $I_{PH}$ . It is desirable  
5 to convert light 11 into an electrical signal externally  
6 available between leads  $V_{out}^+$  and  $V_{out}^-$ . An opposed terminal of  
7 PIN photodiode 10 is electrically connected to a terminal of a  
8 capacitor,  $C_1$ , and a terminal of a resistor,  $R_3$ , at a node 14.  
9 An opposed terminal of  $C_1$  is electrically connected to a  
10 current return 9. An opposed terminal of  $R_3$  is electrically  
11 connected to lead  $V_{cc}$  at node 15. A terminal of a capacitor,  
12  $C_2$ , is electrically connected to node 15 and an opposed  
13 terminal of  $C_2$  is electrically connected to current return 9.  
14 Lead  $V_{cc}$  provides a means for electrical communication with an  
15 electrical power source (not shown) to power optical  
16 preamplifier 5.

17

18       Turn now to FIG. 2 which illustrates a simplified circuit  
19 schematic of an optical preamplifier 6 which includes a  
20 received signal strength indicator (RSSI). Preamplifier 6 is  
21 electrically connected to a PIN photodiode 10 in a similar  
22 manner to preamplifier 5 except a PIN BIAS lead has been added.  
23 The PIN BIAS lead is connected to provide an indication of the  
24 photocurrent,  $I_{PH}$ , of PIN photodiode 10 so that an intensity of  
25 light 11 can be measured. Thus, the PIN BIAS lead acts as a

1 received signal strength indicator. Unfortunately, this  
2 solution to the RSSI measurement requires the addition of an  
3 extra lead (i.e. the PIN BIAS lead). It is well known by those  
4 skilled in the art that the addition of extra leads into a chip  
5 package increases the cost and complexity of the system. Thus,  
6 it is desirable to have a preamplifier circuit with fewer leads  
7 that has the RSSI feature.

8

9 Turn now to FIG. 3 which illustrates a more detailed  
10 circuit schematic of optical preamplifier circuitry 5 without  
11 an RSSI feature, including a preamplifier stage 12.  
12 Preamplifier stage 12 includes cascaded amplifiers, such as  
13 amplifier 18 and amplifier 19 to achieve a desired gain and  
14 frequency response. Preamplifier stage 12 also includes a  
15 current mode logic output stage 16 which includes Darlington  
16 pair transistors 20 and 21 electrically connected to a current  
17 source 17. A resistor,  $R_1$ , is electrically connected between  
18 transistor 20 and  $V_{cc}$  and a resistor,  $R_2$ , is electrically  
19 connected between transistor 21 and  $V_{cc}$ . Also,  $V_{out}^+$  and  $V_{out}^-$  are  
20 electrically connected to a RF coupled current limiting  
21 amplifier 22 through a capacitor,  $C_3$ , and a capacitor,  $C_4$ ,  
22 respectively. Current limiting amplifier 22 includes an output  
23 D and an output  $\bar{D}$ .

1        Turn now to FIG. 4 which illustrates a simplified circuit  
2        schematic of a preamplifier 7 electrically connected to a  
3        photodiode 10, such as a PIN diode or the like, in accordance  
4        with the present invention. Also, a more detailed circuit  
5        schematic of preamplifier 7 is illustrated in FIG. 5.  
6        Preamplifier 7 includes an amplifier 12 with an input  
7        connection 30, a positive voltage output connection 33, a  
8        negative voltage output connection 32, a current return  
9        connection 31, and a power connection 34. Current return  
10      connection 31 is electrically connected to a current return  
11      lead 13, positive voltage output connection 33 is electrically  
12      connected to a lead  $V_{out}^+$ , negative voltage output connection 32  
13      is electrically connected to a lead  $V_{out}^-$ , and power connection  
14      34 is electrically connected to a lead  $V_{cc}$  at a node 15.  $V_{out}^+$   
15      and  $V_{out}^-$  are typically RF coupled to a current limiting  
16      amplifier (not shown). In this embodiment, a terminal of a  
17      resistance  $R_3$  (e.g. a resistor or any device that provides the  
18      resistance for the sensing operation) is electrically connected  
19      to a node 14 and the opposed terminal of resistance  $R_3$  is  
20      electrically connected to lead  $V_{out}^+$ .

21

22        In preamplifier 7, an RSSI output is sensed by measuring  
23        the DC offset between leads  $V_{out}^+$  and  $V_{out}^-$ . Thus, the RSSI  
24        feature has been included in this embodiment without increasing

1 the number of leads. This is especially important when  
2 preamplifier 7 is fabricated as an integrated circuit. The use  
3 of fewer leads in preamplifier 7 reduces the cost and allows a  
4 simpler implementation and an improved performance. For  
5 example, this embodiment allows a more linear voltage between  
6  $V_{out}^+$  and  $V_{out}^-$ .

7

8 Turn now to FIG. 5 which illustrates a more detailed  
9 circuit schematic of optical preamplifier circuitry 7 with an  
10 RSSI feature and including a preamplifier stage. The  
11 preamplifier stage includes cascaded amplifiers 18 and 19  
12 designed to achieve a desired gain and frequency response for a  
13 specific application. The preamplifier stage also has a  
14 current mode logic output stage including Darlington pair  
15 transistors 20 and 21 having a common emitter connection  
16 electrically coupled to a current source 17. A resistor,  $R_1$ ,  
17 is electrically connected between transistor 20 and  $V_{cc}$  and a  
18 resistor,  $R_2$ , is electrically connected between transistor 21  
19 and  $V_{cc}$ . Also,  $V_{out}^+$  and  $V_{out}^-$  are electrically connected to a RF  
20 coupled current limiting amplifier 22 through a capacitor,  $C_3$ ,  
21 and a capacitor,  $C_4$ , respectively. Current limiting amplifier  
22 includes an output D and an output  $\bar{D}$ .

23

24 As illustrated in this detail, the anode of photodiode 10  
25 is coupled to input 30 of cascaded amplifiers 18 and 19 and the

1 cathode is connected to node 14. One terminal of a resistance  
2  $R_3$  is connected to node 14 and the other terminal is connected  
3 to lead  $V_{out}^+$ . One terminal of a capacitor,  $C_1$  is connected to  
4 node 14 and the other terminal is connected to a current return  
5 9. Thus, the RSSI output appears as a DC offset between leads  
6  $V_{out}^+$  and  $V_{out}^-$ . This DC offset is available for measurement at  
7 output D and an output  $\bar{D}$  of current limiting amplifier 22.  
8 Therefore, the RSSI feature has been included in this  
9 embodiment without increasing the number of leads. The use of  
10 fewer leads in preamplifier 7 reduces the cost and allows a  
11 simpler implementation and an improved performance, especially  
12 in an integrated circuit form.

13

14 Thus, a new and improved optical preamplifier with a  
15 received signal strength indicator function is disclosed. The  
16 new and improved optical preamplifier with a received signal  
17 strength indicator function is provided with reduced cost and  
18 complexity, as a result of the preamplifier requiring fewer  
19 leads. Reducing the number of leads in the optical  
20 preamplifier substantially improves the production and use,  
21 especially in an integrated form.

22

23 Various changes and modifications to the embodiments  
24 herein chosen for purposes of illustration will readily occur  
25 to those skilled in the art. To the extent that such

1    modifications and variations do not depart from the spirit of  
2    the invention, they are intended to be included within the  
3    scope thereof which is assessed only by a fair interpretation  
4    of the following claims.

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6       Having fully described the invention in such clear and  
7    concise terms as to enable those skilled in the art to  
8    understand and practice the same, the invention claimed is: